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(54) **DIGITAL SENSING MULTI ACCESS PROTOCOL**

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(52) **U.S. Cl.** **370/330**; 370/348; 370/349

(58) **Field of Search** 370/328, 229, 370/336, 337, 345, 347, 349, 442, 340, 330, 341, 348

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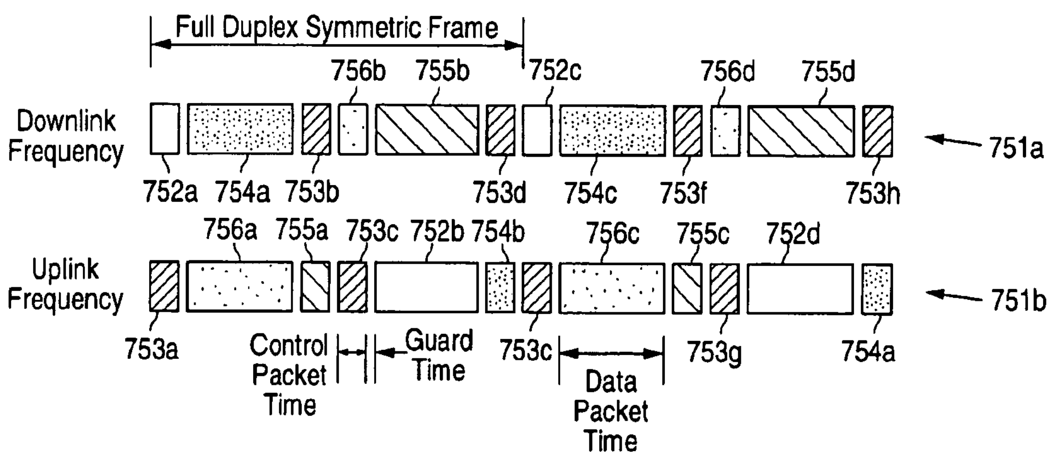
(57) **ABSTRACT**

A wireless data network, including a base station and multiple mobile wireless terminals, implements a synchronous 2-way communication protocol in which the availability of a communication channel is signalled by the base station in a control packet. The multiple mobile wireless terminals compete for acquisition of the communication channel by sending a request packet, upon detecting from the control packet that the communication channel is available. The base station grants the channel by acknowledging the request packet of a selected one of the mobile wireless data terminal. The mobile wireless data terminal communicates with the base station over the communication channel subsequent to acquisition. Upon the wireless data terminal relinquishing the communication channel, the base station sends out the next control packet indicating that the communication channel is again available.

22 Claims, 5 Drawing Sheets



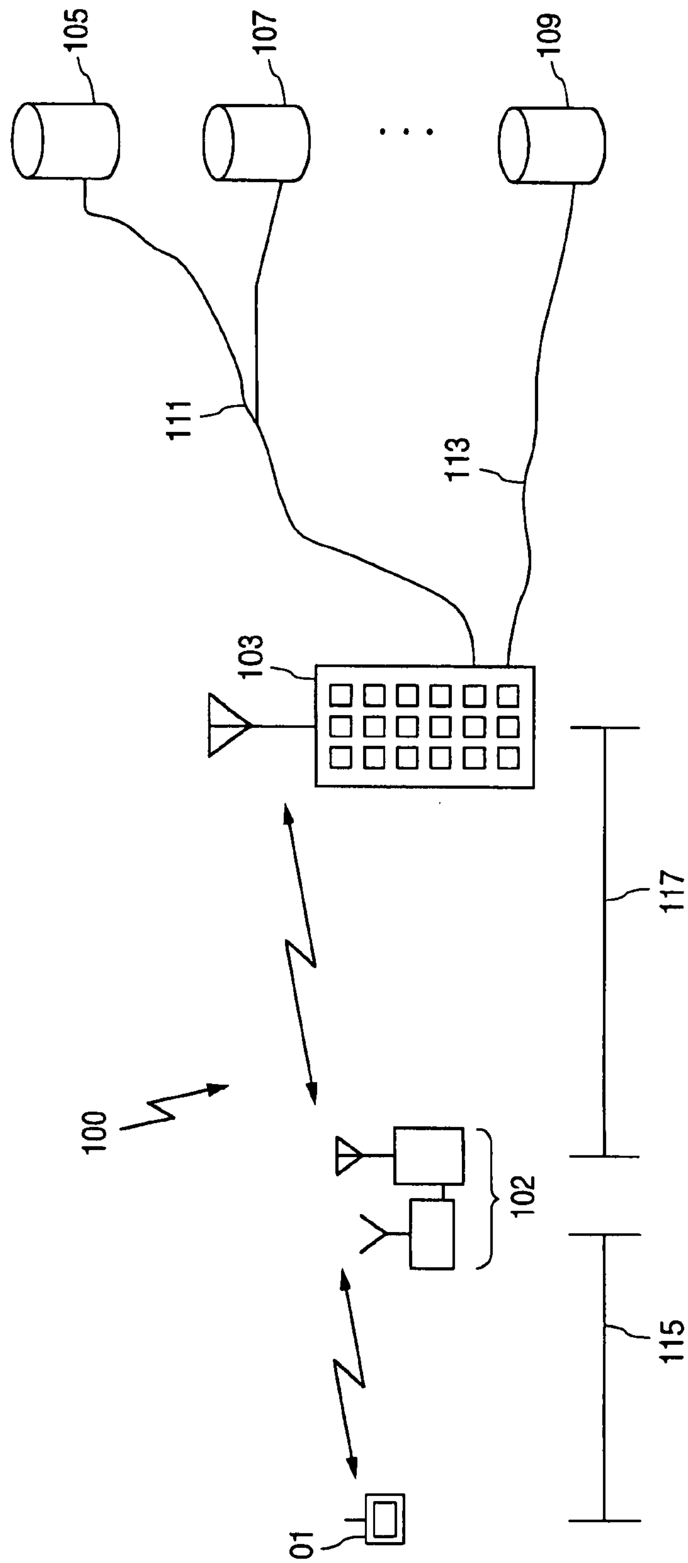


FIG. 1

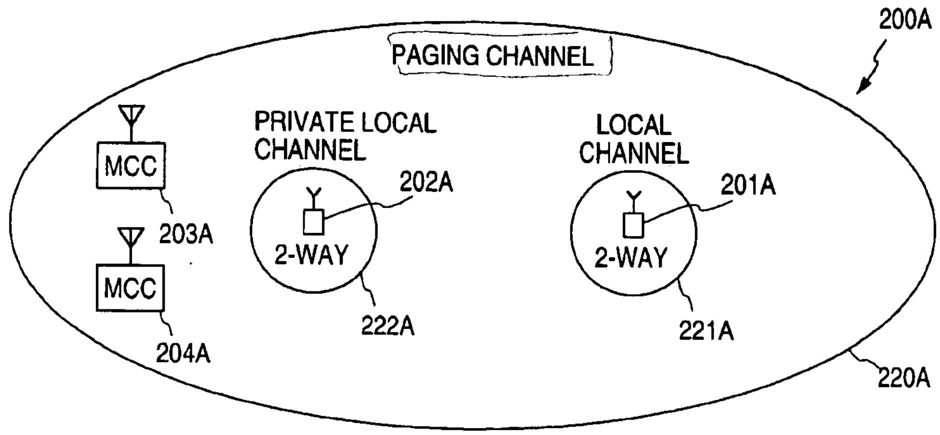


FIG. 2A

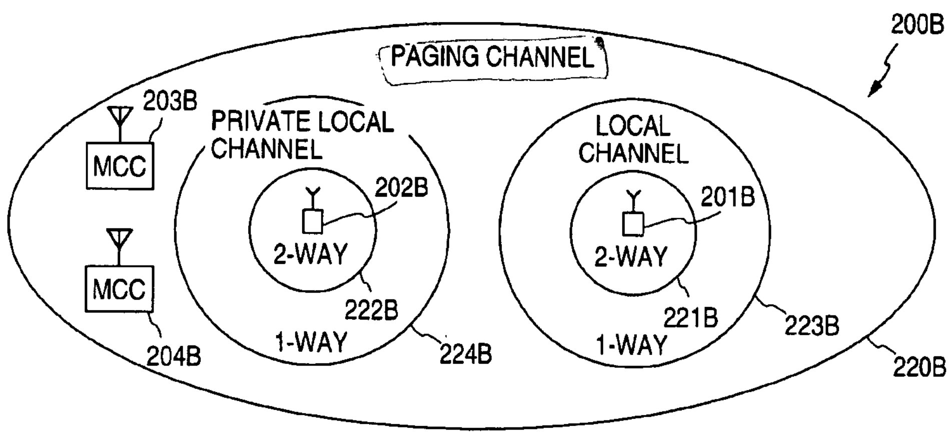


FIG. 2B

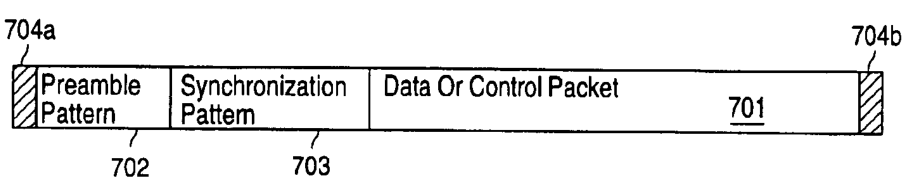
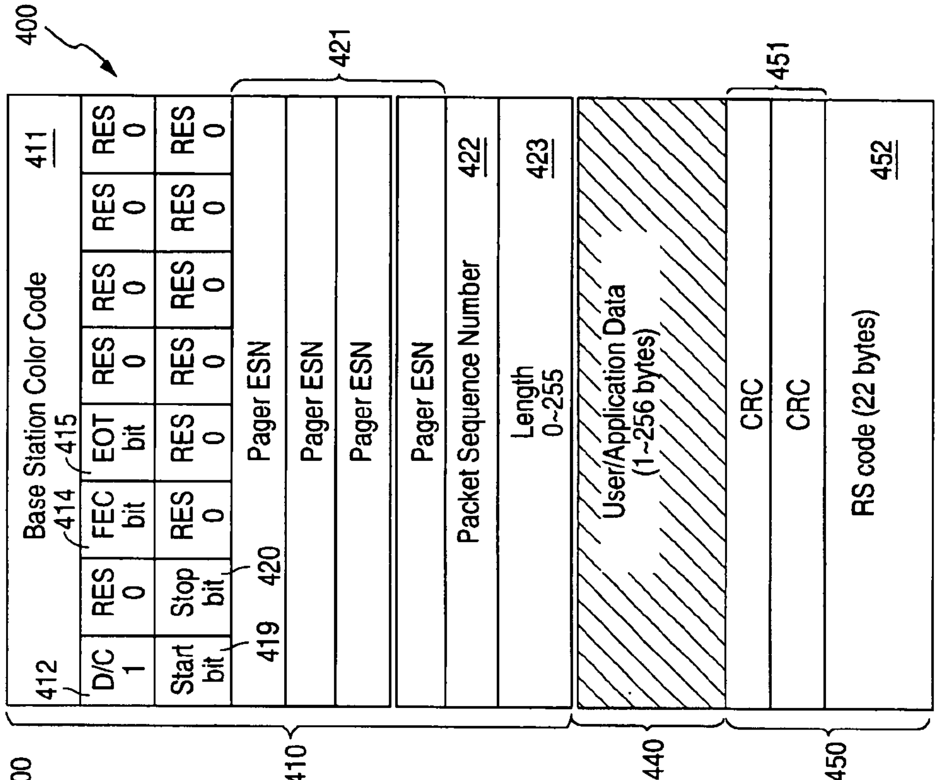
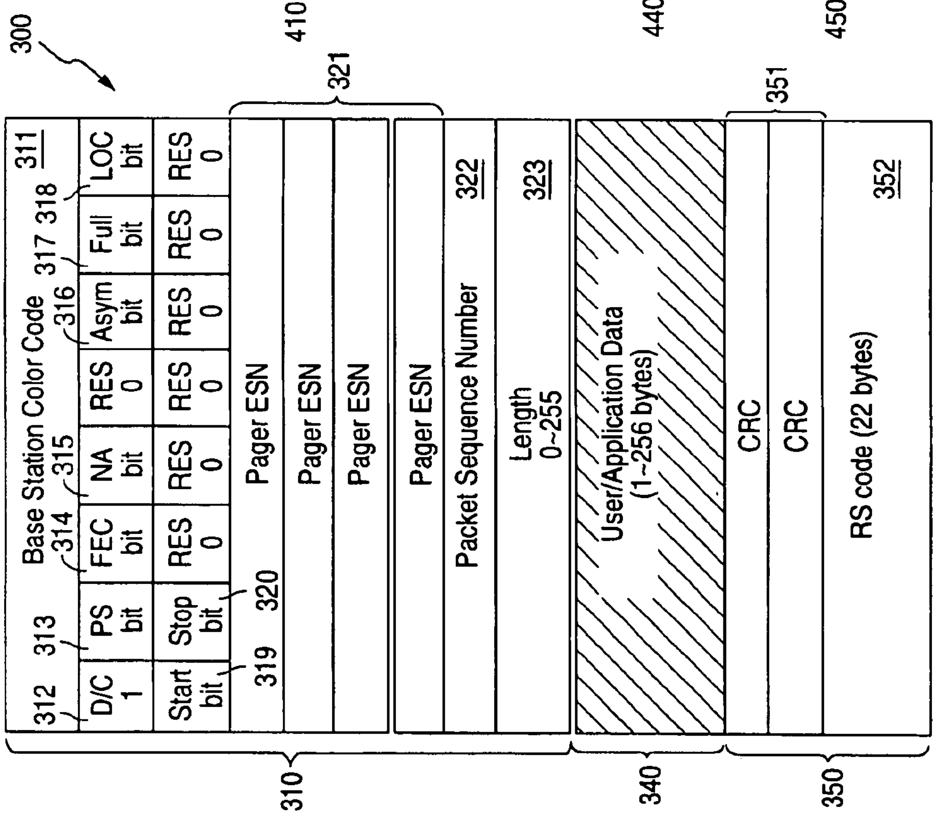


FIG. 7C



400
Base Station Color Code
411
412
D/C 1
RES 0
414
FEC bit
415
EOT bit
RES 0
RES 0
RES 0
RES 0
Start bit
Stop bit
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
419
420
Pager ESN
Pager ESN
Pager ESN
Pager ESN
421
Packet Sequence Number
422
Length 0~255
423
User/Application Data (1~256 bytes)
CRC
CRC
451
RS code (22 bytes)
452
410
440
450

FIG. 4



300
Base Station Color Code
311
312
D/C 1
313
PS bit
314
FEC bit
315
NA bit
RES 0
316
Asym bit
317
Full bit
318
LOC bit
Start bit
Stop bit
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
319
320
Pager ESN
Pager ESN
Pager ESN
Pager ESN
321
Packet Sequence Number
322
Length 0~255
323
User/Application Data (1~256 bytes)
CRC
CRC
351
RS code (22 bytes)
352
310
340
350

FIG. 3

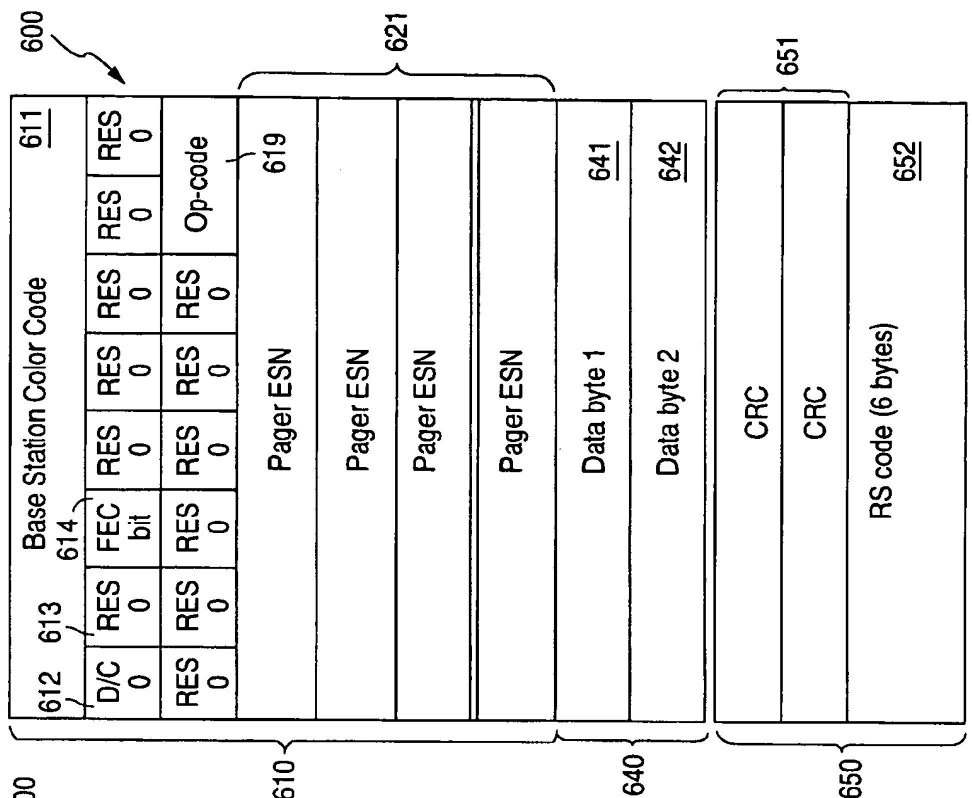

600
Base Station Color Code
611
612
613
614
D/C 0
RES 0
FEC bit
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
Op-code
619
Pager ESN
Pager ESN
Pager ESN
Pager ESN
621
Data byte 1
641
Data byte 2
642
CRC
CRC
651
RS code (6 bytes)
652
610
640
650

FIG. 6

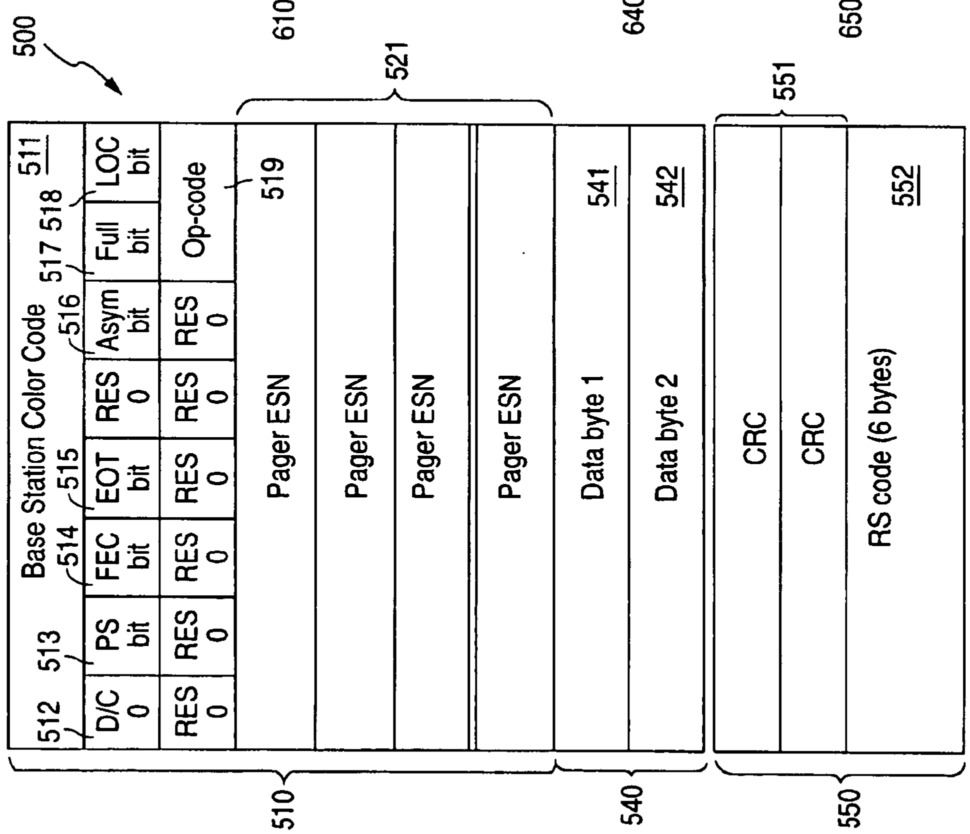

500
Base Station Color Code
511
512
513
514
515
516
517 518
D/C 0
PS bit
FEC bit
EOT bit
RES 0
Asym bit
Full bit
LOC bit
RES 0
RES 0
RES 0
RES 0
RES 0
RES 0
Op-code
519
Pager ESN
Pager ESN
Pager ESN
Pager ESN
521
Data byte 1
541
Data byte 2
542
CRC
CRC
551
RS code (6 bytes)
552
510
540
550

FIG. 5

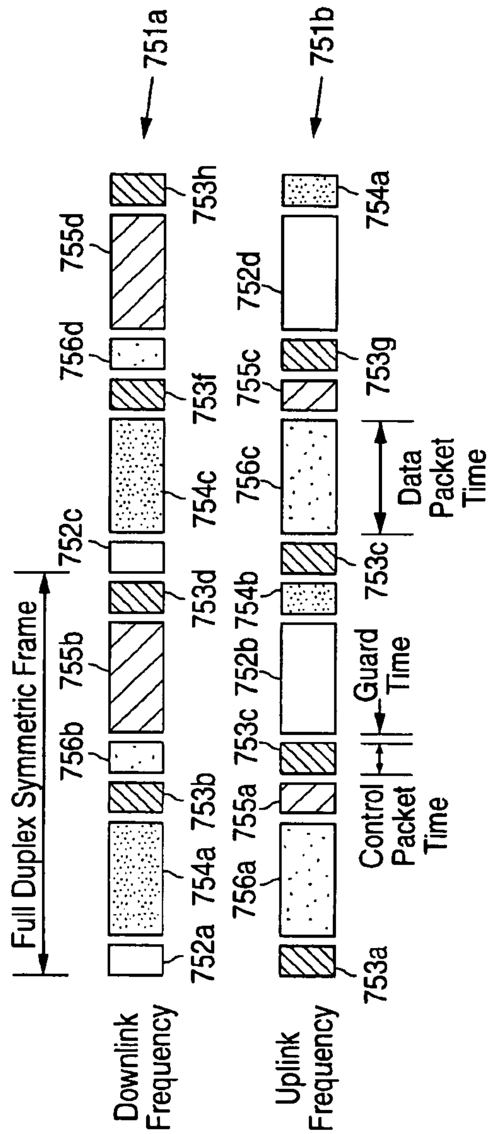

Full Duplex Symmetric Frame
Downlink Frequency
Uplink Frequency
751a
751b
752a
754a
753b
756b
755b
753d
752c
754c
753f
756d
755d
753h
753a
756a
755a
753c
752b
754b
753c
756c
755c
753g
752d
754a
Control Packet Time
Guard Time
Data Packet Time

FIG. 7a

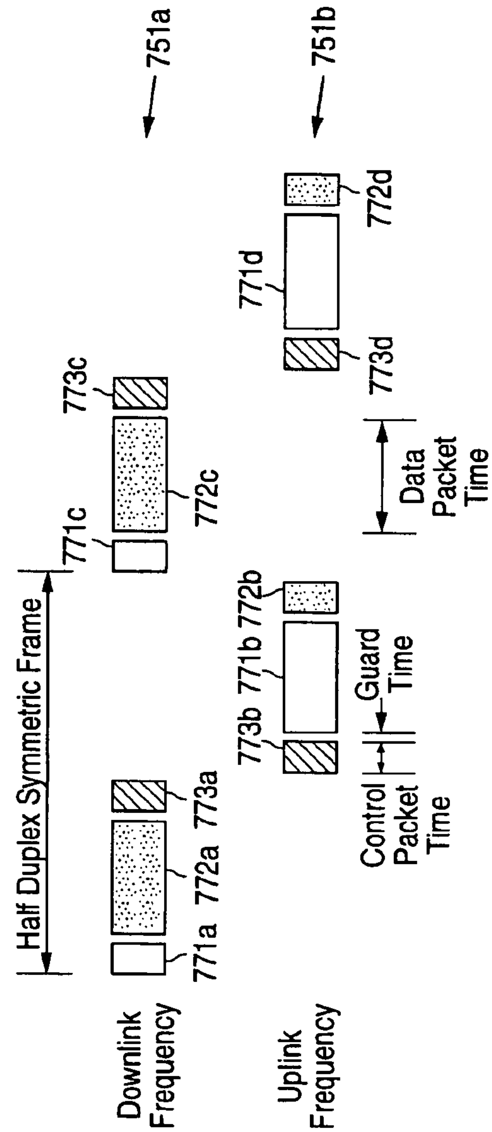

Half Duplex Symmetric Frame
Downlink Frequency
Uplink Frequency
751a
751b
771a
772a
773a
771c
772c
773c
773b
771b
772b
773d
771d
772d
Control Packet Time
Guard Time
Data Packet Time

FIG. 7b

DIGITAL SENSING MULTI ACCESS PROTOCOL

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

The present application is related to copending and commonly assigned U.S. patent application ("Copending Application"), Ser. No. 08/915,078, entitled "COMMUNICATION PROTOCOL FOR A WIRELESS DATA SYSTEM", by Kwok Choi, now abandoned in favor of U.S. patent application, Ser. No. 09/574,686, which is a divisional application of the Copending Application. The Copending Application and the '686 application are incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to wireless data communication; and in particular, the present invention relates to network access protocols used in wireless data communication.

2. Background of the Invention

An example of a network access protocol for a two-way wireless data network is shown in FIG. **1** and described in detail in commonly assigned U.S. Patent Application ("'860 Application"), Ser. No. 08/542,860, entitled "TWO-WAY WIRELESS DATA NETWORK", by Weijia Wang, now U.S. Pat. No. 5,898,904, issued on Apr. 27, 1999. The '760 Application is incorporated herein by reference in its entirety.

As shown in FIG. **1**, a wireless data network **100** includes a wireless data terminal **101**, a cellularized base station **102**, a message control center **103**, interfaces **105**–**109** to information and communication applications, and radio links **115** and **117**. Message control center **103** provides a high power transmitter capable of broadcasting over a paging channel to wireless data terminals within the entire service area of wireless data network **100**. In this manner, wireless data network **100** is compatible with existing one-way paging services. Message control center **103** also communicates with base station **102** through radio link **117** which is a high power transmission (e.g. 3 watts).

Base station **102** is one of a number of base stations that are distributed throughout the service area of wireless data network **100**. Each base station serves a portion of the service area of wireless data network **100** within its immediate vicinity. The local service area of a base station is sometimes called a "cell". The base stations broadcast to wireless data terminals in their respective cells through a local channel. Typically, the base stations cumulatively serve all locations within the service area of the wireless data network **100**. Wireless data terminal **101** communicates with one or more of the base stations, e.g., base station **102**, through radio link **115**. Radio link **115** needs only provide a low power transmission (e.g. 100 mW) to service the local service area. When wireless data terminal is outside the local service area of any base station, wireless data terminal **101** is restricted only to receiving messages from the 1-way paging channel. Other details of the operation of the two-way wireless data network can be found in the aforementioned '860 Application and incorporated by reference above.

Enhancements to the network access scheme described above have been suggested so as to increase the network bandwidth and channel utilization of a two-way wireless

data network. One such enhancement is described the Copending Application incorporated by reference above. The Copending Application discloses a network access protocol, referred to as the capture division packet access (CDPA) protocol, which allows a wireless data terminal to camp onto a local base station for two-way communication whenever the wireless data terminal is within the service range of the base station, thus bypassing the message control center all together. Under the "local override" mode of the CDPA protocol, a wireless data terminal registers with a local base station upon entering the local service area of the local base station, and subsequently communicates with that base station over the local channel. The local override mode avoids the undesired latency associated with high message traffic conditions in the paging channel. The CDPA protocol also supports a "local-only" mode in which the wireless data terminal ignores communication over the paging channel and camps onto the local channel at all times for two-way communication.

The CDPA protocol described in the Copending Application also includes other performance enhancement features. For instance, the CDPA protocol supports asymmetric downlink and uplink coverage areas in the local channel. The coverage pattern, i.e., the downlink coverage area is larger than the uplink coverage area, allows incremental start-up of a new 2-2-way wireless communication system. Under an asymmetric coverage area scheme, a wireless data terminal carries out two-way communication with a base station while within the uplink coverage area, and receives messages from the base station when outside the uplink coverage area but still within the downlink coverage area.

The CDPA protocol described in the Copending Application uses a variable speed retry scheme to avoid collision in the uplink and to extend the range of uplink communication. Under the variable speed retry scheme, when a previous transmission is unsuccessful, a wireless data terminal retransmits the data packet using alternatively a high data rate transmission and a low data rate transmission. Furthermore, the retransmissions are attempted at randomized time intervals so as to minimize collision with other wireless data terminals competing for the uplink. Other aspects of the CDPA protocol are described in details in the Copending Application incorporated by reference above.

The CDPA protocol described above is particularly useful when a wireless data terminal communicates primarily with a small number of local base stations. As described in the Copending Application, an example of such an application is found in a hospital where a user typically receives messages originated and received within the hospital during the normal work day. In that application, the hospital usually can be serviced by at most a small number of base stations under the control of a local message control center, forming what is sometimes referred to as a "private" system. The CDPA protocol supports wireless network communication both within the private system and outside the private system, sometimes referred to as the "public" system.

Performance problems can arise in the application described above where two-way communication is provided by a private system operating within a public system. For example, to provide coverage within a private system, base stations are sometimes installed closer together than they need to be in the counterpart public system. Such close deployment of base stations can result in overlapping coverage areas in the open space within the service area of the private system. When a wireless data terminal is operating in a coverage area of overlap, the wireless data terminal receives communications from more than one base station.

However, interference among these base stations ("co-channel interference") can occur, causing the wireless data terminal to receive no packet at all or unable to transmit to any of the base stations. A network access scheme capable of minimizing co-channel interference improves efficiency of the two-way wireless data network.

In the two-way wireless data network described above, wireless data terminals compete for the uplink bandwidth. Collisions resulting from simultaneous transmissions by two or more wireless data terminals can occur to significantly reduce the channel utilization rate. For instance, packet collisions are very common under the ALOHA protocol because wireless data terminals transmit without regard to channel availability. Collision avoidance schemes, such as the variable speed retry scheme described above, increase channel utilization.

SUMMARY OF THE INVENTION

The present invention provides a network access protocol which minimizes collisions in the uplink communication and reduces the number of retries needed for a successful uplink transmission. The network access protocol implemented according to the present invention, referred to as the digital sensing multiple access protocol with request-to-send and clear-to-send (the "DSMA/RC protocol"), improves channel utilization rate and transmission performance. Under the DSMA/RC protocol, collision is possible only in the first uplink data packet of a message. Subsequent data packets are transmitted without collision.

In one embodiment of the present invention, a method is provided in a two-way communication network. The method includes the steps of: (a) providing a communication channel having first and second sets of time slots; (b) providing a base station serving a service area and having a transceiver for communicating by radio in the communication channel; (c) sending a message from the base station in a first set of time slots indicating whether the communication channel is available; (d) allowing one or more mobile data terminals to transmit a request for access to the communication channel upon receiving the message from the base station; and (e) receiving at the base station the request for access to the communication channel in the second set of time slots, and (f) granting the request for access to the communication channel to the requesting mobile wireless data terminal.

In one implementation of the method, the message indicating communication channel availability is provided in a field within a header of a control packet. The indication of channel availability can be piggy-backed onto an acknowledgment message sent by the base station in response to a previous message received from the mobile wireless data terminal.

A protocol under the present invention can be implemented in both dual-frequency and single-frequency communication channels. Further, the protocol can be implemented in a full-duplex mode or a half-duplex mode.

In one implementation, the communication channel is divided into multiple logical channels. In one implementation, one of the logical channels provides for transmission of data packets from the wireless data terminal to the base station, and transmission of control packets from the base station to the mobile wireless data terminal. The data packets are sent in a predetermined sequence by the mobile wireless data terminal, and acknowledged one by one by the base station in one of the control packets. Each acknowledgment from the base station signals to the mobile wireless data terminal that the base station is ready to receive the next data packet in the predetermined sequence from the mobile wireless data terminal.

The present invention is better understood upon consideration of the detailed description below and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a wireless data network **100** to which the present invention is applicable.

FIG. 2*a* illustrates, in service area **220A** of a wireless data network **200A**, private system **222A** supporting a local override mode of a DSMA/RC protocol, in accordance with the present invention.

FIG. 2*b* illustrates, in service area **220B** of a wireless data network **200B**, private system **222B** operating according to an asymmetric area coverage scheme, in accordance with the present invention.

FIG. 3 shows the data fields of a downlink data packet under the DSMA/RC protocol of the present invention.

FIG. 4 shows the data fields of a uplink data packet under the DSMA/RC protocol of the present invention.

FIG. 5 shows the data fields of a downlink control packet under the DSMA/RC protocol of the present invention.

FIG. 6 shows the data fields of a uplink control packet under the DSMA/RC protocol of the present invention.

FIG. 7*a* illustrates a full duplex operation of the DSMA/RC protocol using physical channels **751***a* and **751***b*.

FIG. 7*b* illustrates a half-duplex operation of the DSMA/RC protocol using physical channels **701***a* and **751***b*.

FIG. 7*c* shows a frame for transmitting a data or control packet **701** under the DSMA/RC protocol.

In the detailed description below, like objects which appear in more than one figure are provided with like reference numerals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a synchronous wireless communication protocol, referred to as "digital-sensing multi-access with request-to-send and clear-to-send control" ("DSMA/RC"), for use within two-way communication systems, including a two-communication system served by both a broadcast communication system (e.g. paging) and a "cellular" two-way communication system. In a cellular two-way communication system, the total service area is provided a number of base stations each serving a designated local service area within the total service area. Communication between a wireless data terminal and a base station can be half-duplex, full-duplex, single-frequency, or dual-frequency. In a dual-frequency system, the uplink (i.e., wireless terminal to base station) and the downlink (i.e., base station to wireless data terminal) use different frequencies. The uplink and the downlink can also operate at different data rates (e.g., 1200 baud for the uplink and 9600 baud for the downlink).

The DSMA/RC protocol supports a wireless data network operating under either a normal mode, a local override mode, or a local-only mode. In the normal mode, the wireless data network includes a message control center broadcasting over the paging channel and local stations communicating with wireless terminals over the local channel. A wireless data terminal camps on the paging channel for a wake-up message from a message control center. Upon receipt of such a wake-up message, the wireless data termi-

nal switches to a local base station for two-way communication. A wireless data network using DSMA/RC can use one or more frequencies for communication between a base station and wireless data terminals.

One embodiment of the present invention is illustrated by a wireless data network **200A** operating under DSMA/RC shown in FIG. 2A. Wireless data network **200A** includes both a public system and a private system within service area **220A**. For the purpose of this description, the private system is referred to by its service area as private system **222A**. The service area of private system **222A** is served by a base station **202A**. Private system **222A** is controlled by a private message control center **204A** and one or more base stations. Wireless data network **200A** also includes areas served by the public system, such as service area **221A** served by base station **201A**. According to the DSMA/RC protocol of the present invention, when a wireless data terminal enters private system **222A**, the wireless data terminal registers with private base station **202A** and camps onto the local channel for two-way communication. When the wireless data terminal exists private system **222A**, the wireless data terminal registers with other public systems within wireless data network **200A** for two-way communication. A local registration scheme such as that disclosed in the aforementioned Copending Application can be adopted in the DSMA/RC protocol for operating the local override mode in wireless data network **200A**. Wireless data network **200A** can also operate, under the DSMA/RC protocol, in the local-only mode. Under the local-only mode, a wireless data terminal does not receive communication from the paging channel. Instead, a wireless data terminal within wireless data network **200A** camps at all times on the local channel to which the wireless data terminal is registered. In one embodiment, the local modes (i.e., local override and local-only) under DSMA/RC are selected by setting a "LOC" bit in the downlink data or control packet. The formats of the data and control packets under DSMA/RC are described in more details below.

A wireless data network under DSMA/RC can support an asymmetric downlink and uplink coverage area pattern. Such a wireless data network is illustrated by wireless data network **200B** of FIG. 2B. In FIG. 2B, a private system **222B** within service area **220B** includes base station **202B**. As shown in FIG. 2B, base station **202B** has an uplink range **222B**, within which a wireless terminal communicates bidirectionally with base station **202B**, and a downlink range **224B**, within which the wireless data terminal only receives messages from base station **202B** via the local channel.

A wireless data network under DSMA/RC can also support asymmetric data transmission rates. Asymmetric data rates can be advantageously employed to extend the uplink distance without correspondingly increasing the power requirements for a wireless data terminal. In accordance with the packet format described below, an "Asym" bit in the downlink packet indicates whether a wireless data terminal should use asymmetric communication. When the Asym bit is reset, the uplink and the downlink data rates are the same (i.e. symmetric), typically at 9600 baud. Alternately, when Asym bit is set, the downlink transmits at a higher data rate (e.g. 9600 baud) while the uplink transmits at a lower data rate, such as 1200 baud. The lower uplink data rate makes possible a longer uplink distance.

The DSMA/RC protocol of the present invention uses time-division multiplexing (TDM) to allocate bandwidths of one or more physicals channel among one or more logical channels. One example of full-duplex operations under the DSMA/RC using two physical channels **751***a* and **751***b* is illustrated by FIG. 7*a*. As shown in FIG. 7*a*, physical channels **751***a* and **751***b*, each assigned a different frequency, are allocated to provide a downlink and an uplink, respectively. Under full duplex operation, both physical channels can be simultaneously active (i.e., transmitting simultaneously). In FIG. 7*a*, a control packet, which is typically a short packet used to provide such control information as acknowledgment or non-acknowledgment ("ACK packet" or "NACK packet"), is transmitted in a frame represented by a small rectangle, and a data packet is transmitted in a frame represented by a large rectangle. The space between rectangles represents "guard" times (i.e., time periods of brief predetermined durations provided to prevent interference between transmissions). As discussed below with respect to FIG. 7*c*, a frame includes either a control packet or a data packet, along with certain preamble and synchronization information.

As shown in FIG. 7*a*, physical channels **751***a* and **751***b* are divided among five logical channels: message channels **752**, **754**, **755** and **756** and a "command" channel **753**. Message channels **752** and **756** are uplink message channels which allows data packets to be sent from wireless data terminals to a base station, and control packets to be sent from the base station to the wireless data terminals. For example, as shown in the FIG. 7*a*, data packets in frames **756***a* and **756***c* are data packets of message channel **756** from one or more wireless data terminals assigned to message channel **756** to a base station, and control packets in frames **756***b* and **756***d* are control packets of message channel **756** from the base station to the wireless data terminals. Similarly, control packets in frames **752***a* and **752***c* are control packets of message channel **752** sent from the base station to the wireless data terminals assigned to message channel **752**, and data packets in frames **752***b* and **752***d* are data packets from the wireless data terminals of message channel **752** to the base station. Message channels **754** and **755** are downlink message channels, which operate analogously as described above for message channels **752** and **756**, except that data packets are sent from the base station to the wireless terminals of message channels **754** and **755**, and control packets are sent from the wireless data terminals of message channels **754** and **755** to the base station.

Command channel **753** is used for transmitting control packets only, and the command channel time slots in both physical channels **751***a* and **751***b* are assigned to the base station and the wireless data terminals in a predetermined pattern. The pattern shown in FIG. 7*a*, for example, assigns the time slots for control packets in frames **753***a*–**753***h* alternately between downlink communication (physical channel **751***a*) and uplink communication (physical channel **751***b*).

The DSMA/RC protocol can also be implemented for half-duplex operations (i.e., downlink communication and uplink communication cannot occur simultaneously). FIG. 7*b* shows an implementation of half-duplex operations of the DSMA/RC protocol using physical channels **751***a* and **751***b*. As shown in FIG. 7*b*, under a half-duplex operation, physical channels **751***a* and **751***b* are divided among three logical channels: message channels **771** and **772**, and command channel **773**. As shown in FIG. 7*b*, message channel **771** allows transmission of uplink data packets (e.g., data packets in frames **771***b* and **771***d*) from the wireless data terminals to a base station, and transmission of downlink control data packets (e.g. control data packets in frames **771***a* and **771***c*) from the base to the wireless data terminals. In an analogous manner, message channel **772** allows transmis-

sion of downlink data packets (e.g., data packets in frames **772a** and **772c**) from base station to the wireless data terminals, and transmission of uplink control data packets (e.g. data packets in frames **772b** and **772d**) from the wireless data terminals to the base station. Command channel **773** sends control packets (e.g., control packets in frames **773a**–**773d**) in both physical channels **751a** and **751b** under a predetermined TDM pattern. As shown in FIG. 7*b*, time slots are allocated in physical channels **751a** and **751b** in an alternating pattern. The command channel is typically used for such function as local registration (i.e. notification by a wireless data terminal to a base station that the wireless data terminal is in the base station's local service area). In this embodiment, local registration is initiated by a wireless data terminal sending a "local registration request" (LRR) control packet (e.g., control packet in frame **753a**) of command channel **753** in physical channel **751b**, and completes when the base station returns a "local registration granted" (LRG) in a control packet (e.g., control packet in frame **753b**) of command channel **753** in physical channel **751a**.

Half-duplex operation under the DSMA/RC protocol can also be implemented using a single frequency (i.e., a single physical channel). For example, if physical channels **751a** and **751b** use the same frequency, the implementation shown in FIG. 7*b* would illustrate operations of three logical channels 771–773 under the single-frequency half-duplex mode of the DSMA/RC protocol.

Although FIGS. 7*a* and 7*b* each illustrate physical channels **751a** and **751b** to be symmetrical (i.e., providing the same data rate), asymmetric implementations, i.e., different data rates in the uplink and downlink physical channels can be implemented. In asymmetric implementations, since the packet time in each physical channel is different, the number of message channels, or the number of time slots allocated to each logical channels, assigned to each physical channel is often different to ensure efficient use of the respective bandwidths. In the present embodiment, synchronization between the base station and the wireless data terminals for implementing any mode of the DSMA/RC protocol is provided by the base station. The base station can acquire its time base in a number of ways, for example, through signals received from the Global Positioning System (GPS) or by monitoring a broadcast source. The wireless data terminal acquires its time base by monitoring a synchronization sequence in the downlink communication.

FIG. 7*c* shows a frame **700** for transmitting a control or data packet **701** under the DSMA/RC protocol. As shown in FIG. 7*c*, in frame **700**, control or data packet **701** is preceded by a 16-bit preamble pattern **702** and a 16-bit synchronization pattern **703**. As mentioned above, to prevent transmissions from interfering with each other, sufficient guard time, indicated by ramp-up time **704a** and ramp-down time **704b** are provided before and after transmission of each packet, respectively. Preamble pattern **702** identifies whether the data or control packet is sent from a base station to a wireless data terminal, or from a wireless data terminal to a base station. Synchronization pattern **703** indicates the beginning of control or data packet **701**. In the present embodiment, data packets and control packets are each provided with different formats for uplink and downlink communications. The downlink data packet format and the uplink data packet format under the DSMA/RC protocol of the present invention are illustrated respectively by downlink data packet **300** in FIG. 3 and uplink data packet **400** in FIG. 4. Similarly, the downlink control packet and the uplink control packet under the DSMA/RC protocol of the present invention are illustrated respectively by downlink control packet **500** in FIG. 5 and uplink control packet **600** in FIG. 6.

Under the DSMA/RC protocol, the wireless data terminals compete for the uplink. To acquire the uplink, each wireless data terminal monitors control packets in the message channel to which it is assigned. A base station signals the availability of an uplink message channel by setting in each of the data and control packets an asserted end-of-transmission (EOT) flag. A deasserted EOT flag signals that the uplink message channel is busy. This method of monitoring and signalling the availability of a communication channel is known in the art as "digital sensing." The base station sends "beacon" data and control packets when a message channel remains available. A beacon data or control packet is a dummy packet provided to signal that an active base station is present. In this embodiment, where local service areas of two or more base stations overlap, beacon data or control packets may not be sent to avoid co-channel interference.

To acquire an uplink, subsequent to detecting that a message channel is available, a wireless data terminal sends a first data packet at the next data packet time slot of the message channel. When the first data packet from a wireless data terminal is received, the base station grants the uplink message channel to the requesting wireless data terminal by designating a requesting wireless data terminal in an ACK control packet corresponding to the data packet received by the base station. This ACK control packet acts as a "clear-to-send" (CTS) control signal. If the ACK control packet is then received by the designated wireless data terminal, that wireless data terminal can send additional data packets in the uplink message channel. If the wireless data terminal does not receive an ACK control packet corresponding to its first data packet, the wireless data terminal retries the first data packet up to a programmable number of times at later times whenever the message channel becomes idle (i.e., using a "p-persistent" retry strategy). Upon granted the message channel, a wireless data terminal camps on the uplink and downlink physical channels until communication completes and the uplink is relinquished. Under the DSMA/RC protocol, each data packet is acknowledged by an ACK packet, which also serves as a "request-to-send" (RTS) signal for the next data packet.

Digital sensing avoids collision because a wireless data terminal will attempt to acquire an uplink only after detecting that a message channel is idle. Thus, collision occurs only among wireless data terminals in competing for an uplink message channel. Once an uplink message channel has been granted to a wireless data terminal, the uplink message channel is provided for the exclusive use by the wireless data terminal until the message channel is relinquished. Under the DSMA/RC protocol, traffic from the base station does not collide because the control or data packets are transmitted in reserved time slots.

In the case in which beacons are not sent when an uplink message channel is idle, to avoid co-channel interference, the DSMA/RC protocol operates in a manner similar to the Aloha protocol known in the art. Under that scheme, a wireless data terminal requests a message channel after detecting the absence of activity in the physical channel for a predetermined time duration.

As shown in FIG. 3, downlink data packet **300** includes a header portion **310**, a data payload portion **340**, and an error correction portion **350**. Header portion **310** includes (i) a one-byte "Base Station Color code" field **311**, identifying the base station to which the packet relates; (ii) a 1-bit "Data/Control" (D/C) field **312** set to "1", identifying packet **300** as a data packet; (iii) a 1-bit "Packet Sync" (PS) field **313**, indicating whether the uplink packet is synchronous

with the current packet; (iv) a 1-bit "FEC" field **314**, indicating that the wireless data terminal shall perform Reed-Solomon forward error correction function; (v) a 1-bit "No ACK" (NA) field **315**, indicating whether an acknowledgment (ACK) packet is required in response to the current data packet; (vi) a 1-bit "Asym" field **316**, indicating whether the wireless data terminal should use asymmetric data rates as described above; (vii) a 1-bit "Full" field **317**, indicating whether the channel is full duplex or half duplex; (viii) a 1-bit "Local" (LOC) field **318**, indicating whether a data packet is send under the local modes described above; (ix) a start bit **319**, indicating whether the current packet is the first packet of a message; (x) a stop bit **320**, indicating whether the current packet is the last packet of a message; (xi) a 4-byte "Pager ESN" field **321**, uniquely identifying the wireless data terminal; (xii) a 1-byte "Packet Sequence Number" field **322**, identifying the packet order information to be used to re-assemble the message; and (xiii) a 1-byte "length" field **323**, specifying the number of bytes in the data packet. Header portion **310** further includes seven "Reserved" (RES) bits whose functions are reserved for future expansion. All RES bits are set to the value of "0". Error correction portion **350** includes (i) a 2-byte "Checksum" field **351**, representing the cyclic redundancy checksum of the packet from the beginning of data packet **300** to the last byte of data in payload **340**; and (ii) 22 check bytes of RS code, **352** for error correction

Uplink data packet **400** (FIG. **4**) includes a header portion **410**, a data payload **440**, and an error correction portion **450**. Uplink data packet **400** includes fields that are similar to those in downlink data packet **300**. Hence, similarly named fields in uplink data packet **400** are not further described. Header portion **410** of uplink data packet **400** includes (i) a one-byte "Base Station Color code" field **411**; (ii) a 1-bit "Data/Control" (D/C) field **412** set to "1", identifying packet **400** as a data packet; (iii) a 1-bit "FEC" field **414**; (iv) a 1-bit "End-of-Transmission" (EOT) field **415**; (v) a start bit **419**; (vi) a stop bit **420**; (vii) a 4-byte "Pager ESN" field **421**; (viii) a 1-byte "Packet Sequence Number" field **422**; and (ix) a 1-byte "length" field **423**. EOT field **415** of data packet **400** indicates whether the current packet is the last packet of the last message of a connection.

In this embodiment, the following types of control packets are provided: (i) an ACK packet used in both the uplink and the downlink; (ii) a NACK packet used in both the uplink and the downlink; (iii) a Wake-Up Response packet from a wireless data terminal to a base station; (iv) an LRR packet from a wireless data terminal to a base station requesting registration; and (v) an LRG packet from a base station to a wireless data terminal indicating that local registration is completed. The wake-up response, LRR and LRG packets are used in a command channel.

FIG. **5** illustrates the format of a downlink control packet **500**. Downlink control packet **500** includes a header portion **510**, a fixed-length data payload **540**, and an error correction portion **550**. Fields in downlink control packet **500** that are the same as in downlink data packet **300** are not further described. Header portion **510** includes (i) a one-byte "Base Station Color code" field **511**; (ii) a 1-bit "Data/Control" (D/C) field **512** set to "0", identifying packet **500** as a control packet; (iii) a 1-bit "Packet Sync" (PS) field **513**; (iv) a 1-bit "FEC" field **514**; (v) a 1-bit "EOT" field **515**; (vi) a 1-bit "Asym" field **516**; (vii) a 1-bit "Full" field **517**; (viii) a 1-bit "Local" (LOC) field **518**; and (ix) a 2-bit "Op-code" **519**, identifying the function of control packet **500**. Data payload **540** of downlink control packet **500** contains two bytes of data, first data byte **541** and second data byte **542**, which are associated with the functions of downlink control packet **500**. For instance, in an ACK packet, first data byte **541** contains the value of the received data packet's sequence number (PSN) plus 1. In an NACK packet, first data byte **541** contains the value of the received data packet's PSN. In an LRG packet, first data byte **541** is set to "1" to indicate that local registration request is granted. For the other types of control packet, such as Wake-Up Response and LRR, first data byte **541** is not used. In all types of control packets, second data byte **542** contains the System ID, identifying the wireless data network. Following data payload **540**, error correction portion **550** includes (i) a 2-byte "Checksum" field **551**, representing the cyclic redundancy checksum of the packet from the beginning of data packet **500** to the last byte of data in payload **540**; and (ii) a 6-byte Reed Solomon code **552** for error correction function.

Uplink control packet **600**, as shown in FIG. **6**, is similar to downlink control packet **500**. Similarly named fields in uplink control packet **600** are not further described. Header portion **610** of uplink control packet **600** includes (i) a one-byte "Base Station Color code" field **611**; (ii) a 1-bit "Data/Control" (D/C) field **612** set to "0", identifying packet **600** as a control packet; (iii) a 1-bit "FEC" field **614**; and (iv) a 2-bit "Op-code" **619**. Data payload **640** of uplink control packet **600** is defined in the same manner as data payload **540** of downlink control packet **500**.

Data integrity can be enhanced by the use of error correcting codes, such as Reed-Solomon (RS) code. In this embodiment, a 17-byte RS code, including 6 "check" bytes is used for a control packet, and a 66-byte RS code, including 22 check bytes is used for a data packet. Other techniques, such as interleaving or bit scrambling, can be used to further enhance transmission integrity by avoiding long runs of 1's or 0's.

The above detailed description are provided to illustrate the specific embodiments of the present invention and is not intended to be limiting. Numerous modifications and variations within the scope of the present invention are possible. The present invention is defined by the appended claims thereto.

We claim:

1. A two-way wireless data network, comprising:

a communication channel providing first and second sets of time slots;

a plurality of mobile wireless data terminals each having a transceiver for communicating by radio in said communication channel, said plurality of mobile wireless data terminals being assigned said second set of time slots for transmitting a request for access to said communication channel;

a base station serving a service area and having a transceiver for communicating by radio in said communication channel, said base station sending a message in said first set of time slots indicating whether said communication channel is available;

wherein said plurality of mobile wireless data terminals monitor said communication channel for said message from said base station; a first one of said plurality of mobile wireless data terminals transmits said request for access in said second set of time slots upon receiving said message; and said base station, upon receiving said request for access, grants said request for access to said communication channel to said first one of said plurality of mobile wireless data terminals.

2. The two-way wireless data network of claim **1** wherein said message is provided in a field within a header of a control packet.

3. The two-way wireless data network of claim 2, wherein said message comprises an acknowledgment message sent by said base station in response to a previous message received from another one of said plurality of mobile wireless data terminals.

4. The two-way wireless data network of claim 1, wherein said communication channel uses a first frequency for said first set of time slots and a second frequency for said second set of time slots.

5. The two-way wireless data network of claim 1, wherein said first and second sets of time slots are non-overlapping.

6. The two-way wireless data network of claim 1, wherein said communication channel is divided into multiple logical channels.

7. The two-way wireless data network of claim 6, wherein said multiple logical channels include a logical channel in which data packets are sent from said plurality of mobile wireless data terminals to said base station, and control packets are sent from said base station to said plurality of mobile wireless data terminals.

8. The two-way wireless data network of claim 7, wherein said data packets are sent in a predetermined sequence by said first one of said plurality of mobile wireless data terminals, wherein each data packet is acknowledged by said base station in one of said control packets, and wherein upon receiving said control packet in which said data packet is acknowledged, said first one of said plurality of mobile wireless data terminals sends the next data packet in said predetermined sequence.

9. In a two-way wireless data network, a method comprising:

providing a communication channel having first and second sets of time slots, said second set of time slots being assigned to a plurality of mobile wireless data terminals;

providing a base station serving a service area and having a transceiver for communicating by radio in said communication channel;

sending a message from said base station in said first set of time slots indicating whether said communication channel is available;

monitoring said communication channel for said message by said plurality of mobile wireless data terminals;

transmitting in said second set of time slots a request for access to said communication channel from a first one of said plurality of mobile wireless data terminals upon receiving said message, each of said plurality of wireless data terminals having a transceiver for communicating by radio in said communication channel; and

receiving at said base station said request for access to said communication channel, and granting said request for access to said communication channel to said first one of said plurality of mobile wireless data terminals.

10. The method of claim 9 wherein said message is provided in a field within a header of a control packet.

11. The method of claim 10, wherein said message comprises an acknowledgment message sent by said base station in response to a previous message received from another one of said plurality of mobile wireless data terminals.

12. The method of claim 9, wherein said communication channel uses a first frequency for said first set of time slots and a second frequency for said second set of time slots.

13. The method claim 9, wherein said first and second sets of time slots are non-overlapping.

14. The method of claim 9, wherein said communication channel is divided into multiple logical channels.

15. The method of claim 14, wherein said multiple logical channels include a logical channel in which data packets are sent from said plurality of mobile wireless data terminals to said base station, and control packets are sent from said base station to said plurality of mobile wireless data terminals.

16. The method of claim 15, wherein said data packets are sent in a predetermined sequence by said first one of said plurality of mobile wireless data terminals, wherein each data packet is acknowledged by said base station in one of said control packets, and wherein upon receiving said control packet in which said data packet is acknowledged, said first one of said plurality of mobile wireless data terminals sends the next data packet in said predetermined sequence.

17. The two-way wireless data network of claim 1, wherein said request for access comprises a first data packet sent by said first one of said plurality of mobile wireless data terminals.

18. The two-way wireless data network of claim 1, wherein said base station grants said request for access to said first one of said plurality of mobile wireless data terminals by transmitting a control packet designating said first one of said plurality of mobile wireless data terminals.

19. The two-way wireless data network of claim 1, wherein said plurality of mobile wireless data terminals refrain from transmitting said request for access when said message received from said base station indicates that said communication channel is not available.

20. The method of claim 9, wherein said transmitting in said second set of time slots a request for access to said communication channel from a first one of said plurality of mobile wireless data terminals comprises:

transmitting a first data packet from said first one of said plurality of mobile wireless data terminals upon receiving said message.

21. The method of claim 9, wherein said granting said request for access to said communication channel to said first one of said plurality of mobile wireless data terminal comprises:

transmitting a control packet designating said first one of said plurality of mobile wireless data terminals.

22. The method of claim 9, wherein said plurality of mobile wireless data terminals refrain from transmitting said request for access when said message received from said base station indicates that said communication channel is not available.

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